

at the focus of the mirror and in the optical axis of the same.

The driving motion of the clock is transmitted to the telescope by two sectors, one of which is being run back ready to be put into gear again whilst the other is being used; each sector allows of one hour's exposure being made. The "following" is performed by means of an auxiliary telescope rigidly attached to the plate holder (*Scientific American*, May 16).

THE RELATIONSHIPS BETWEEN ARC AND SPARK SPECTRA.—In No. 4, vol. xvii. of the *Astrophysical Journal* there appears an advance translation, by the author, of a paper on the above subject recently communicated to the K. Akademie der Wiss. zu Berlin by Prof. J. Hartmann.

In his experiments on the arc spectrum of magnesium, using metallic poles, he found that the line at λ 4481, which is generally regarded as essentially a "spark" line, appears in the arc spectrum, and actually increases in intensity as the current strength becomes less—this is plainly shown in a table which accompanies the paper. From this and similar results the author arrives at the conclusion that the higher temperature of the spark, as compared with that of the arc, is open to question.

Further experiments showed that a high voltage was not necessary for the production of "spark" lines in the arc, for when a current of 20 volts and 4 amperes was used the line 4481 was about thirty times more intense than when 120 volts and 4 amperes were used.

Prof. Hartmann arrives at the conclusion that the energy of the electric discharge and of the chemical changes may play a more important part in the production of "spark" lines than temperature does, and in his experiments, in which the arc was formed in an atmosphere of hydrogen, he has shown that the dielectric is also an important factor in determining the nature of the spectrum obtained.

RADIO-ACTIVE PROCESSES.¹

THERE are three distinct types of radiation spontaneously emitted from radio-active bodies, which may be called the α , β , and γ rays. The α -rays are prominent in causing the conductivity of a gas, they are easily absorbed by metals, and are projected bodies, not waves. These bodies are about the size of a hydrogen atom, they are positively charged, and travel with about one-tenth of the velocity of light. The β -rays are similar in all respects to the cathode rays produced in a vacuum-tube. The γ -rays are probably like Röntgen rays, but of very great penetrating power. The α -rays are by far the most important. In addition to these rays two of the radio-elements give off radio-active "emanations," which are in all respects like gases. The radiations from these emanations are not permanent, but fall off in a geometrical progression with the time. The radiation of the thorium emanation falls to half value in one minute, that from radium in four days. They have all the properties of gaseous matter in infinitesimal quantity. Their coefficients of diffusion can be measured, the order of their molecular weights is 100, they are occluded by solid compounds producing them, and may be condensed at low temperatures. The radium emanation condenses sharply at -150° C., the thorium emanation between -120° C. and -150° C. The two emanations excite on objects with which they come in contact two kinds of temporary radio-activity, that from the radium emanation decaying much faster than that from the thorium emanation. The latter decays in a G.P. with the time falling to half value in eleven hours. These effects appear to be produced by solid matter in invisible and unweighable quantity, which can be dissolved off in some acids but not in others. On evaporating the solutions, the radio-activity is obtained unchanged in the residue. The experiments of Crookes and Becquerel in separating by chemical treatment the matter responsible for the activity of uranium, called uranium X, were referred to, together with the latter's observation that the separated activity had completely decayed after the lapse of a year, by which time the uranium itself had completely recovered its activity. The work of Rutherford and

Soddy on thorium was then discussed in detail. Thorium precipitated in solution by ammonia retains only 25 per cent. of its activity. If the solution is evaporated and ignited the remaining 75 per cent. is found in the extremely small residue left, which by reason of its separation is different chemically from thorium, and was called thorium X. Left to themselves, the thorium gradually recovers its activity, and the ThX loses it. The activity of the latter falls in a G.P. with the time, the half value being reached after four days. At any time the sum total of the two activities is a constant. This would occur if the ThX were being continually produced by the thorium, and this was shown to be the case by precipitating thorium at definite intervals after its separation from ThX. The ThX, and not thorium, produces the thorium emanation. The production of ThX by thorium, of the emanation by ThX, and of the matter causing the excited activity by the emanation, are all changes of the same type, although the rates of change are distinct in each case. The change of uranium into uranium X is also similar, being the slowest of all. Twenty-two days elapse before uranium freed from ThX recovers one-half of its activity. In radium the radium emanation is the first product produced, and since this in a solid is almost completely occluded, the activity of a radium salt after it has been obtained from its solution rises after precipitation to several times its original value, due to the occlusion of the emanation. In all three radio-elements a part of the radio-activity is non-separable, and this part consists only of α -rays. The β -rays only result at the last stages of the process that can be experimentally traced. In all cases the radiation, from any type of active matter, is a measure of the amount of the next type produced. Thus the radio-activity of ThX at any period throughout its life is always a measure of the amount of emanation it produces. These results find their explanation if it is supposed that the α -particles projected form integral portions of the atom of the radio-active element. Thus ThX is thorium minus one or more projected α -particles. The emanation similarly is ThX less a further α -particle, and so on. The non-separable activity is due to the atoms of the original radio-element disintegrating at a constant rate. The whole of the processes take place unaltered in velocity, apparently under all conditions of temperature, state of aggregation, and chemical combination. This is to be expected of a subatomic change in which one system only is involved at each change. On this view the spontaneous heat-emission of solid radium salts, discovered by Curie, is explained by the internal bombardment by the α -particles shot off and absorbed in the mass of the substance. The amount of energy given out in these subatomic changes is enormous, and from Curie's experiments it can be deduced that each gram of radium gives out 10^9 gram-calories during its life, which is sufficient to raise 500 tons a mile high. It seems probable that the internal energy of atoms in general is of a similar high order of magnitude.

SOME UNSOLVED PROBLEMS IN ENGINEERING.¹

THE present lecture is devoted to the indication of some of the directions in which the further aid of the physicist is more immediately required by the engineer, while it is hoped that in future lectures each branch of inquiry thus pointed out will be dealt with in detail by someone who has made that particular subject his special study.

In view of the great interests—monetary and otherwise—involved, it appears to me that the whole question of steam-jacketing, and particularly the application of such jackets to compound or multiple-expansion engines of modern types and of large power, using steam at high pressures, deserves a much more thorough and systematic investigation than it has hitherto received.

The action of steam-jackets is, however, only one of several important problems relating to steam-engine economy at present remaining unsolved. Another is the

¹ Abstract of paper read before the Physical Society on June 5, by Prof. E. Rutherford, F.R.S.

¹ Abridged from the eleventh "James Forrest" lecture delivered by Mr. W. H. Maw to an Engineering Conference on June 16, at the Institution of Civil Engineers.

economic effect of interheaters, through which the steam is passed on its way from one cylinder to another, of a compound or triple-expansion engine. During the past half-century, numerous types of interheaters have been designed and applied more or less spasmodically; while, in recent years, the use of such appliances has become a prominent feature in certain branches of American practice. The data on which the use of such heaters is founded, however, are far from being of a satisfying character, and they present discrepancies which certainly require clearing up.

What is really required is accurate information as to the extent to which our most advanced steam-engine practice can—especially in the case of large power units—be improved by the use of superheated steam, and as to the manner in which such improvement can best be realised. In connection with this matter, I may point out that we are much in want of a thorough determination of the physical properties of superheated steam, extending over the range of temperatures and pressures likely to be employed in practice. Such a determination may, I hope, soon be undertaken. Equally desirable also is the thorough investigation of the action of steam—both saturated and superheated—in the various types of turbine motors, a matter which has, as yet, been by no means dealt with so exhaustively as its great, and rapidly growing, practical importance deserves, and respecting which many lessons undoubtedly remain to be learnt.

In addition to the various points already mentioned, the question of the economy to be secured by the use of still higher pressures of steam than are now used requires investigation. We are without any direct determination of the latent heat, volume, and temperature corresponding to pressure in the case of steam of pressures exceeding 350 lbs. per square inch. The published data relating to steam of higher pressures have been obtained by extrapolation, and are by no means strictly to be relied upon.

The thorough investigation of the theory and practical working of internal-combustion engines presents for solution problems at once so numerous and so varied as to tax to the utmost the skill and ingenuity of the experimenter. There appears to be good ground for believing that with an increase of temperature there is a very substantial increase in the specific heats of such gases. While, however, the general fact may be regarded as proved, the numerical data necessary to enable that conclusion to be turned to practical account are far from having been fixed with certainty, and further determinations are greatly wanted.

The value of experiments on internal-combustion engines depends in a most important degree upon the accuracy with which variations of temperature can be observed, both in the cylinder before and during explosion, and in the walls of the chamber in which the explosion occurs. As Prof. Callendar has pointed out, the temperature assumed by the platinum wire of an electric resistance thermometer exposed to such gases must necessarily be less than that of the gases themselves. Moreover, the rate at which heat is communicated from the gases to the wire is dependent not only upon the difference of temperature, but also on the pressure, in a way not yet accurately known; and thus the accurate determination of the results of explosions in internal-combustion engines means not merely the skilful use of known appliances, but the determination of certain physical constants involving much expenditure of time and labour. Then, again, the effect of the injection of water or water-vapour into the cylinder in itself offers much scope for investigation, as does also the influence of the quality and quantity of the lubricating oils on the gaseous mixture. The governing of internal-combustion engines and the regulation of the powers developed by them at various speeds and under varying conditions are also matters which present many unsolved problems.

In the case of large bridges, roofs, and structural work of that class, there is ample scope for aid to be given by the better determination of the amount and effect of wind-pressure—a branch of experimental inquiry which is at present far from being in a satisfactory state. What is greatly required is a thorough investigation of the action of the wind on surfaces of different areas and shapes, and particularly its effect on partially shielded areas. Amongst other points requiring settlement is the action of wind on the lee-side of roofs—a matter on which the experiments of

Irminger have thrown much light, but which still requires further investigation.

In the determination of the stresses induced in the elements of a structure by the forces applied to that structure, there still remain many problems of importance imperfectly solved. The theory of the plate-web girder, for instance, is in a far from satisfactory state, particularly as regards the action of web stiffeners, the stresses on the web itself, and those on the connections between the web and the flanges. The whole subject of resistance to compound stresses—such, for instance, as those existing in the web of a plate girder or a flat stayed plate, forming part of a steam boiler—is one urgently requiring further experimental investigation.

Then, again, we are now largely using hollow shafts for marine and other purposes, and the relation of these to solid shafts of the same nominal strength, as regards the power of resisting repetitions of varying or alternating stress, has not yet been systematically investigated. Another point is the effect of oil-tempering and different modes of annealing on the endurance of fatigue, a matter which, in view of the effect of similar treatments on the ultimate strength and limit of elasticity of steel, is one of much importance.

The great problem we have still to face—and it is a problem which will tax to the utmost our powers of research—is the determination of what the change which we call elastic fatigue really is. The indications of ordinary testing machines do not reveal any change in the behaviour of a material which has certainly exhausted a large proportion of its “life” under repeated applications of stress, and we must evidently, to solve the problem, have recourse to other modes of inquiry. What is the change of structure produced by fatigue, and in the case of any but pure metals is this change accompanied by any rearrangement of the constituents? How is this change of structure affected by variations of treatments, by annealing, or, in the case of steel, by tempering?

It is sometimes of considerable importance to ascertain whether a certain object, as, for instance, a propeller shaft, or a portion of a bridge structure, or a steel rail, has or has not been injured by the repeated applications of stress to which it has been subjected; and at present the only method of determining this is the testing to destruction of the object respecting which the information is desired. But if we knew accurately in what part of the object the stresses to which it had been subjected would first cause injury, and if we further knew in what way the existence of such injury would be indicated by change of structure, it would follow that the microscopic examination of a small portion, cut from the most sensitive part of the object, would afford a valuable indication of what was going on.

There are other questions which appeal directly to the users of steel. Amongst such questions are the oil-tempering of mild steel forgings and of steel castings; the investigation of the treatment during manufacture and hardening of spring steel; the examination of the qualities of special steel alloys, suitable for the construction of engine or machine details, in which exceptional strength and lightness are essential; and the production of alloys capable of resisting corrosion and withstanding great changes of temperature, and thus specially suitable for the construction of superheaters and other apparatus in which such changes occur.

We have in new steels a series of materials which promise to revolutionise a very important percentage of our machine work, and to necessitate very material alterations in the proportions of our machine tools, involving very heavy outlay, if we wish to advance with the times. Now these are facts pointing to the necessity for extensive research conducted in a thoroughly systematic way.

I have endeavoured to show how desirable it is that the engineer and the physicist should work together in dealing with certain investigations which I have enumerated, and I have done so because, although engineers generally now fully appreciate the aid which physical science can afford, there has not hitherto been such an intimate association of the two classes of workers as is really desirable. But with electrical engineering the case is quite different. We are accustomed to speak of the extraordinarily rapid development of electrical engineering, and the marvellous way in which it is assuming such a paramount position in civilised life,

but I do not remember ever hearing this wonderful growth attributed to what I believe to be its real cause, namely, that from the moment that the practical application of electricity became one of the branches of our profession, engineers and physicists have worked closely hand in hand to overcome its difficulties, and to elucidate the questions to which it gives rise. The growth of electrical engineering thus constitutes a great object-lesson, sufficient in itself abundantly to emphasise the fact that the future progress of engineering is indissolubly bound up with the progress of physical research.

THE SOUTH AFRICAN ASSOCIATION.

REVIEWING the brief history of the events which culminated in the first annual meeting of the South African Association for the Advancement of Science, the early proceedings of which were described in our issue for May 21, Sir David Gill, the president, announced some of the facilities which had been offered to induce the British Association to visit South Africa in 1905. The president read a letter he had received from Sir Gordon Sprigg, the Prime Minister of Cape Colony, stating that free railway passes will be granted over the Cape Railway system for all officials of the British Association, and a limited number of invited guests; and that a sum not exceeding 6000*l.* will be guaranteed towards the cost of passages to and from the Cape for the above-mentioned officials and visitors. This amount will be shared by the Governments of the Transvaal, Natal and the Cape. Sir David Gill went on to say that the other Governments had undertaken to share one-half of this responsibility, and to grant similar free use of their railways. There will be no lack of private hospitality, and the council of the British Association will recommend to the general committee of the Association at the Southport meeting next September that the invitation to hold the annual meeting in 1905 in South Africa be accepted.

Reference was also made to the value of a closer alliance between the results of scientific research and everyday practice in commercial pursuits, the classical works of several of the earlier investigators being mentioned as examples of the far-reaching effects of thorough and precise researches into common everyday phenomena. Sir David Gill then proceeded to enlarge upon the practical value of scientific research, and the reasons for its encouragement in the universities and colleges, and mentioned the unselfish work of Profs. Beattie and Morrison in undertaking the magnetic survey of South Africa, during 1897 and subsequent years, entirely at their own cost. He strongly urged that facilities should now be granted to them for completing this most important work, which fills a gap in the observations that are now being carried out in various parts of the world simultaneously with those being made by the various Antarctic expeditions in the South Polar regions.

Two papers read before Section A of the South African Association contained interesting statistics as to different aspects of the mining industries of the new colonies. In a paper on "Nitro-Glycerine Explosives: their Influence on Industrial Development," Mr. William Cullen, of the Modderfontein Dynamite Factory, stated that by means of explosives alone above 12,000,000 tons of ore had been milled in the Transvaal in the year prior to the war, but no estimate could be formed of the many million additional tons removed in developing shaft-sinking and so on. The old dynamite is rapidly becoming a thing of the past, and the more modern blasting gelatin has gradually supplanted everything else. Perhaps the most interesting part of the paper was that where the final triumph of nitro-glycerine in cordite and many similar powders was demonstrated, proving it to be not only the strongest disruptive agent, but also the mildest and easiest managed impellent.

Mr. W. A. Caldecott, in a paper on the "Cyanide Process from its Introduction into the Rand to the Present Day," said the immense importance of the process was shown by the fact that just before the war half the gold from the Rand was obtained by the cyanide process. By way of comparison, the writer stated that the Rand gold output in 1890 was 494,523 ounces milled, and only 286 ounces obtained by cyanide process. In three years the pro-

portion grew to 1,147,960 ounces milled, and 330,510 ounces by cyanidation.

The records of meteorological observations made at the dynamite factory of Modderfontein, which extend over a large number of years, and form probably the most complete Transvaal meteorological record available, were discussed by Mr. William Cullen in Section A. Rainfall, barometric pressure, temperature (maximum, minimum and average), atmospheric moisture, wind velocity and wind direction were some of the meteorological data passed in review. All were illustrated by diagrams. The rainfall for the various years was analysed, and it was pointed out where a departure from the normal had great influence on the agricultural interests of the Transvaal, and on the prevalence of cattle diseases. The average rainfall for the past five years was 25 inches, the highest being 30.6, and the lowest 20.1, and the observations seemed to show that it was on the increase. The barometric readings showed a very slight variation all through the year, the maximum difference of about 14 generally coming in June, but every twenty-four hours the maximum and the minimum records always occurred at the same time.

Prof. S. Schönland, in a paper to Section B on stone implements in the Albany Museum, emphasised the persistence of the Palæolithic age in South Africa as compared with other countries. While, he said, the manufacturers of stone implements in South Africa were not devoid of skill which must excite our admiration, while their arrow-heads of perforated stone, their rolling-pins, their stone rings, indicated that there was not only skill, but an inheritance of trade tricks handed down from generation to generation, which were faithfully adhered to by the masters of the craft, it was astonishing that so far it had been impossible to find any evidence of progress in the manufacture of stone implements in South Africa, such as we knew had taken place in other countries from Palæolithic times to the time when stone implements were given up. Generally speaking, it could be seen that not only had the Stone age persisted in South Africa until comparatively recent times, but that the Palæolithic age had persisted there to the same extent. This was especially shown in the entire absence of polished stone implements.

Dr. J. D. F. Gilchrist dealt in the same section with the development of some South African fishes. It has been commonly alleged that the practice of netting, as carried on in the Zwartkops, the Buffalo, and other tidal rivers of South Africa, has proved destructive to the eggs and spawn of fish. On the commencement of trawling by the Government steamer in False Bay and on the Agulhas Bank, it was urged that the dragging of the net along the bottom of the sea caused the destruction of great quantities of the eggs and young of food fishes. The evidence obtained by an inquiry held by a Parliamentary Commission seems to indicate that many of the common fishes may deposit their eggs on the bottom of the sea. On the other hand, in all the instances where the mature eggs had been procured and successfully fertilised on the Government steamer *Pieter Faure*, they were found to float on the surface of the water, and only after the larvæ had been hatched out some time did they begin to sink to the bottom. It was also brought to the notice of the Commission that it had already been demonstrated in northern waters that there was only one fish of practical economic importance depositing its eggs on the bottom—the herring—and only a small species of herring of little value to the present fishermen occurs in the Cape seas. Recently facilities have been afforded by Government for more careful examination on shore of the eggs and larvæ procured by means of fine nets and from the mature fish. The eggs and larvæ were described of the white stumpnose, red stumpnose, silver fish, sand fish, zeverrim or zee-basje, kabeljaauw, horse fish, red gurnard, klip-fish (two species), sole (two species), and the blaasop, and the ova and larvæ of fish as yet unknown. The general effect of the investigations so far carried out was to confirm that the trawling did not interfere with the eggs of fishes that were of practical commercial value.

At a concluding general meeting of the Association on the last day of the proceedings, the council of the Association for the present year was elected in accordance with nominations received from the chief centres in Cape Colony, Rhodesia, Transvaal, Natal, and Orange River Colony.